



Environmental Energy Technologies Division Lawrence Berkeley National Laboratory

中美中心零碳模块节能设计

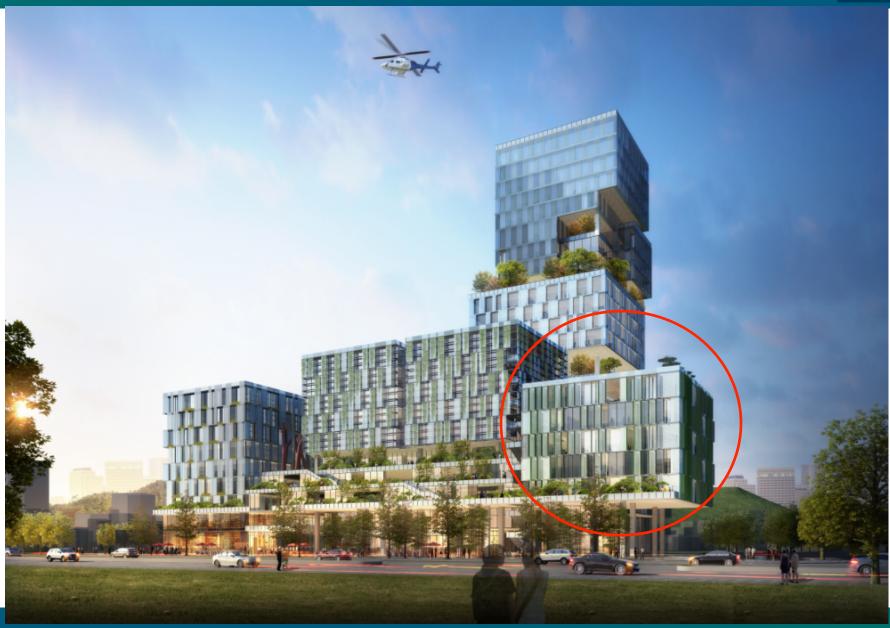
Wei Feng
Lawrence Berkeley National Laboratory

Shenzhen Jan 2018



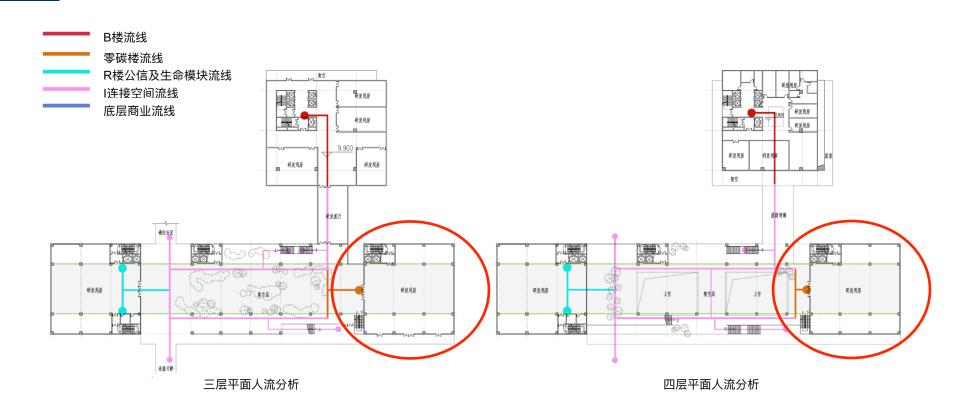








整体流线优化



研究工作介绍



- 协助IBR设计中美中心零碳模块5000m2建筑
- 搭建模拟分析模型, 计算建筑能耗性能
- 着重设计建筑围护结构,照明采光和暖通空调系统
- 着重分析外遮阳影响自然采光,开窗和自然通风,以及暖通空调系统系统性能分析
- 第一期: 2017十月~2018年1月, 围护结构外遮阳, 以及自然 通风
- 第二期: 2018年2月~4月,自然通风和热舒适,暖通空调
- 第三期: 2018年5月~8月, 暖通空调
- 第四期: 2018年9月~12月,报告与汇总

产出:

- 中美中心零能耗模块设计方法
- 夏热冬冷地区净零能耗建筑设计导则



Model Settings 模型基本参数设置

	Office area	Staircase	New-air system	
	Construction			
Roof U value (W/m ² K)		0.64		
External wall U value (W/m ² K)		1.2		
Floor U value (W/m ² K)		1.2		
Window U value (W/m ² K)		1.623		
Window SHGC		0.316		
Activity, Lighting and HVAC				
Occupancy density (People/m²)	0.1			
Lighting density (W/m²)	5 2 0			
Equipment density (W/m²)	5	0	0	
Cooling system	Fan Co	oil Unit, Water cooled	chiller	
	Natural Ventilation	on		
Cooling method	Mechanic	al Cooling + Natural V	Ventilation	
Cooling schedule	Mechanical Cooling: May to Oct;			
	Natural Ventilation: Jan to Apr & Nov to Dec.			
Window opening	15%			
Outdoor temperature limits	Min: 10°C, Max: 30°C			

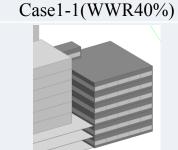


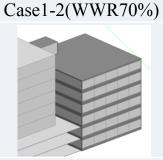
Part 1: Window to Wall Ratio

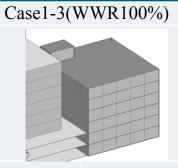
第一部分, 窗墙比

WWR and Shades

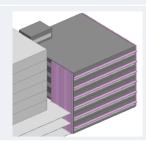


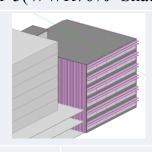


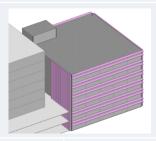




	EUI(kWh/m²)in total area	EUI(kWh/m²)in conditioned area	Lighting(kWh/m²)	Cooling (kWh/m²)	Leed qualified area (%)
Case1-1	39.38	46.16	4.4	15.81	87.7
Case1-2	42.84	50.21	2.95	18.88	99.7
Case1-3	46.62	54.65	2.62	21.34	100
Case1-4(WWI	R40%+Shade)	Case1-5(WW	R70%+Shade)	Case1-6(WWI	R100%+Shade)







	EUI(kWh/m²)in total area	EUI(kWh/m²)in conditioned area	Lighting(kWh/m²)	Cooling (kWh/m²)	Leed qualified area (%)
Case1-4	37.93	44.47	5.73	13.71	74.7(Fail)
Case1-5	37.89	44.42	3.67	14.68	96.1
Case1-6	40.31	47.25	3.05	16.32	99.6

Notes: Double horizontal shade in south (1m), vertical shade in east and west(0.6m wide and 0.6m interval).

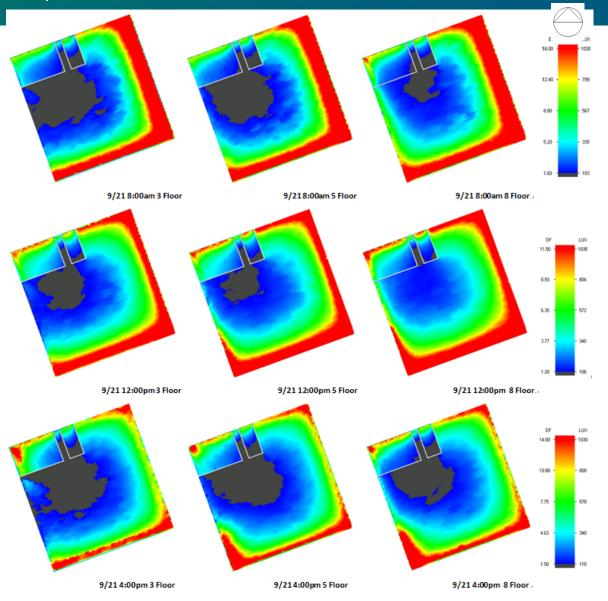


- •A daylighting credit is available if at least 75% of net lightable area in occupied spaces is adequately daylit, having illuminance within the range 10-500 fc.
- •The results below were calculated using the Radiance simulation engine which provides a detailed multi-zone physics-based calculation of illumination levels on the working planes of the building.

Daylighting data			
Sky model	CIE clear day		
Time 1	9:00, 21 Sep		
Time 2	15:00, 21 Sep		
Location	SHENZHEN		
Working plane height (m)	0.750		
Max Grid Size (m)	0.200		
Min Grid Size (m)	0.050		
Illuminance lower threshold (lux)	110.000		
Illuminance upper threshold (lux)	5400.000		

Case 1-1: WWR 40%





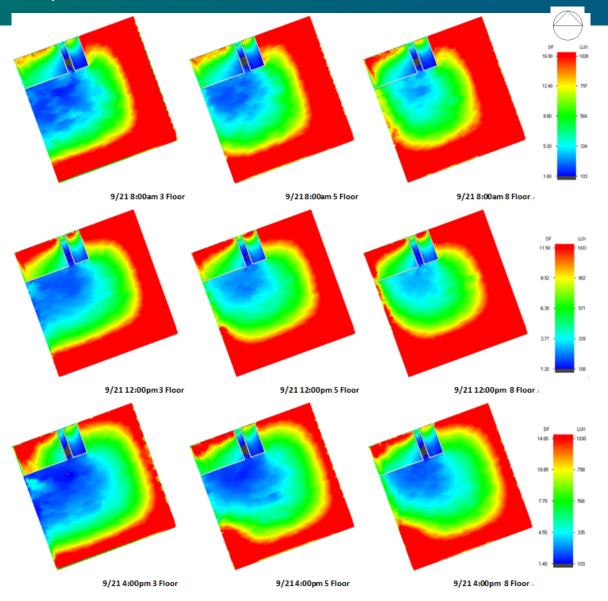
	Energy Per Total Building Area [kWh/ m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	39.38	46.16
Net Site Energy	39.38	46.16

Summary Results	
Total area (m2)	4433.259
Total area above threshold (m2)	3908.905
% Area within illuminance threshold limits	88.2
LEED v3 NC 2009 IEQ 8.1 Status	PASS

Zone	Floor area (m2)	Min Illumination (lux)	Working plane area within Limits (%)
Floor3:OfficeArea	630.341	34.5	82.2
Floor4:OfficeArea	630.341	34.6	86.5
Floor5:OfficeArea	630.341	29.2	85.9
Floor6:OfficeArea	630.341	26.1	87.4
Floor7:OfficeArea	630.341	30.5	88.4
Floor8:OfficeArea	630.341	28.9	92.6

Case 1-2: WWR 70%





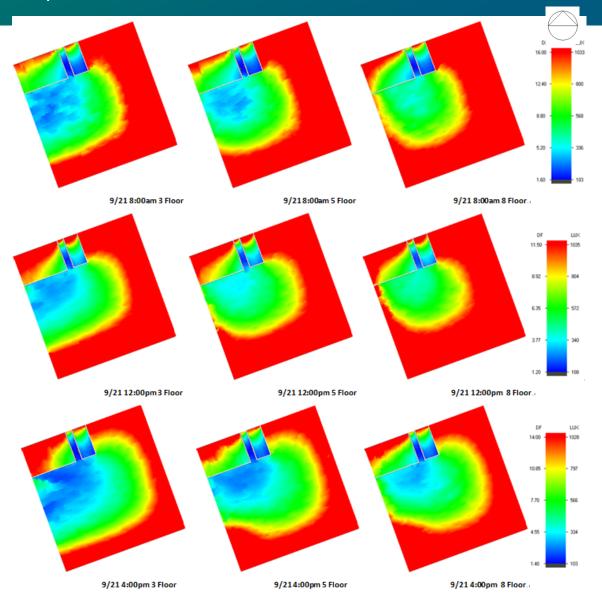
	Energy Per Total Building Area [kWh/ m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	42.84	50.21
Net Site Energy	42.84	50.21

Summary Results	
Total area (m2)	4433.259
Total area above threshold (m2)	4422.161
% Area within illuminance threshold limits	99.7
LEED v3 NC 2009 IEQ 8.1 Status	PASS

Zone	Floor area (m2)	Min Illumination (lux)	Working plane area within Limits (%)
Floor3:OfficeArea	630.341	82.6	99.8
Floor4:OfficeArea	630.341	80.4	99.8
Floor5:OfficeArea	630.341	77.0	99.7
Floor6:OfficeArea	630.341	82.9	99.7
Floor7:OfficeArea	630.341	82.4	99.8
Floor8:OfficeArea	630.341	86.4	99.8

Case 1-3: WWR 100%





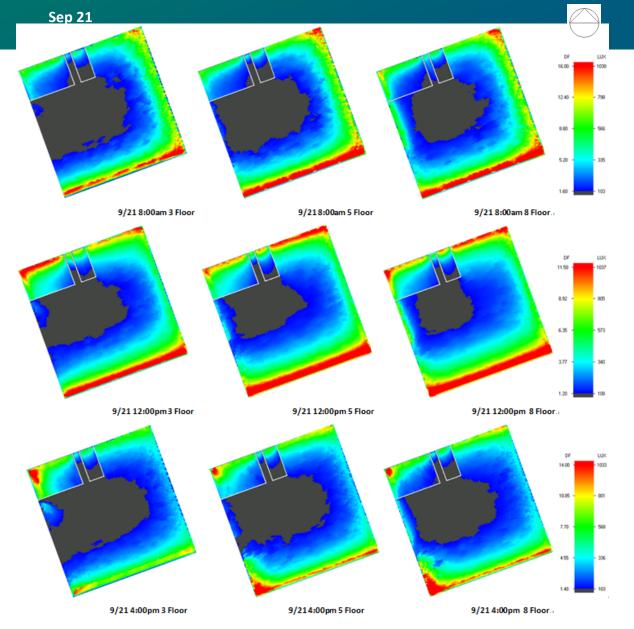
	Energy Per Total Building Area [kWh/ m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	46.62	54.65
Net Site Energy	46.62	54.65

Summary Results	
Total area (m2)	4433.259
Total area above threshold (m2)	4432.086
% Area within illuminance threshold limits	100.0
LEED v3 NC 2009 IEQ 8.1 Status	PASS

Zone	Floor area (m2)	Min Illumination (lux)	Working plane area within Limits (%)
Floor3:OfficeArea	630.341	109.0	100.0
Floor4:OfficeArea	630.341	112.1	100.0
Floor5:OfficeArea	630.341	111.9	100.0
Floor6:OfficeArea	630.341	122.7	100.0
Floor7:OfficeArea	630.341	109.8	100.0
Floor8:OfficeArea	630.341	120.9	100.0







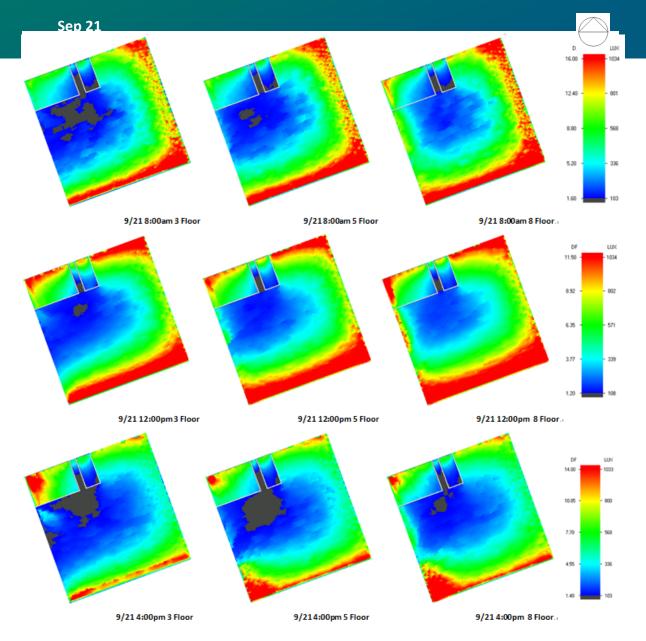
	Energy Per Total Building Area [kWh/ m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	37.93	44.47
Net Site Energy	37.93	44.47

Summary Results	
Total area (m2)	4433.259
Total area above threshold (m2)	3312.757
% Area within illuminance threshold limits	74.7
LEED v3 NC 2009 IEQ 8.1 Status	FAIL

Zone	Floor area (m2)	Min Illumination (lux)	Working plane area within Limits (%)
Floor3:OfficeArea	630.341	27.9	68.4
Floor4:OfficeArea	630.341	16.6	69.9
Floor5:OfficeArea	630.341	19.5	72.1
Floor6:OfficeArea	630.341	16.9	71.2
Floor7:OfficeArea	630.341	18.7	71.5
Floor8:OfficeArea	630.341	27.6	76.5







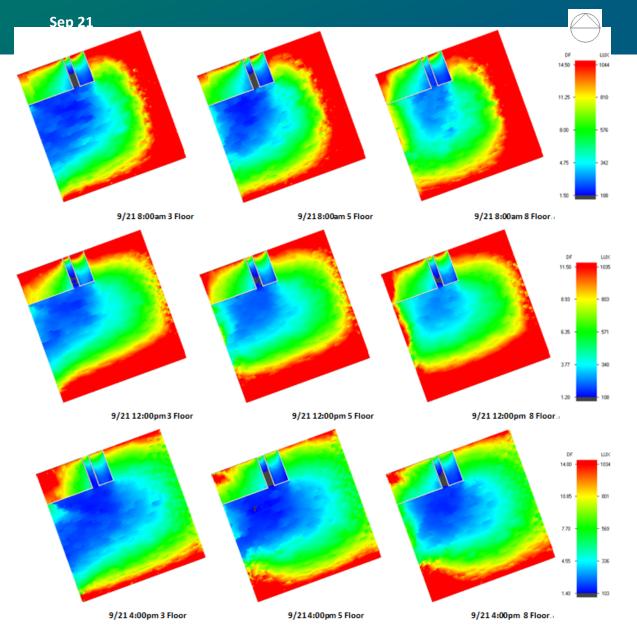
	Energy Per Total Building Area [kWh/ m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	37.89	44.42
Net Site Energy	37.89	44.42

Summary Results	
Total area (m2)	4433.259
Total area above threshold (m2)	4260.881
% Area within illuminance threshold limits	96.1
LEED v3 NC 2009 IEQ 8.1 Status	PASS

Zone	Floor area (m2)	Min Illumination (lux)	Working plane area within Limits (%)
Floor3:OfficeArea	630.341	52.0	94.3
Floor4:OfficeArea	630.341	50.1	96.9
Floor5:OfficeArea	630.341	50.1	93.8
Floor6:OfficeArea	630.341	39.0	94.6
Floor7:OfficeArea	630.341	41.9	94.7
Floor8:OfficeArea	630.341	54.0	99.3







	Energy Per Total Building Area [kWh/ m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	40.31	47.25
Net Site Energy	40.31	47.25

Summary Results	
Total area (m2)	4433.259
Total area above threshold (m2)	4416.498
% Area within illuminance threshold limits	99.6
LEED v3 NC 2009 IEQ 8.1 Status	PASS

Zone	Floor area (m2)	Min Illumination (lux)	Working plane area within Limits (%)
Floor3:OfficeArea	630.341	93.2	99.9
Floor4:OfficeArea	630.341	68.8	99.5
Floor5:OfficeArea	630.341	70.9	99.6
Floor6:OfficeArea	630.341	71.9	99.5
Floor7:OfficeArea	630.341	72.4	99.6
Floor8:OfficeArea	630.341	70.2	99.5

Conclusions on WWR

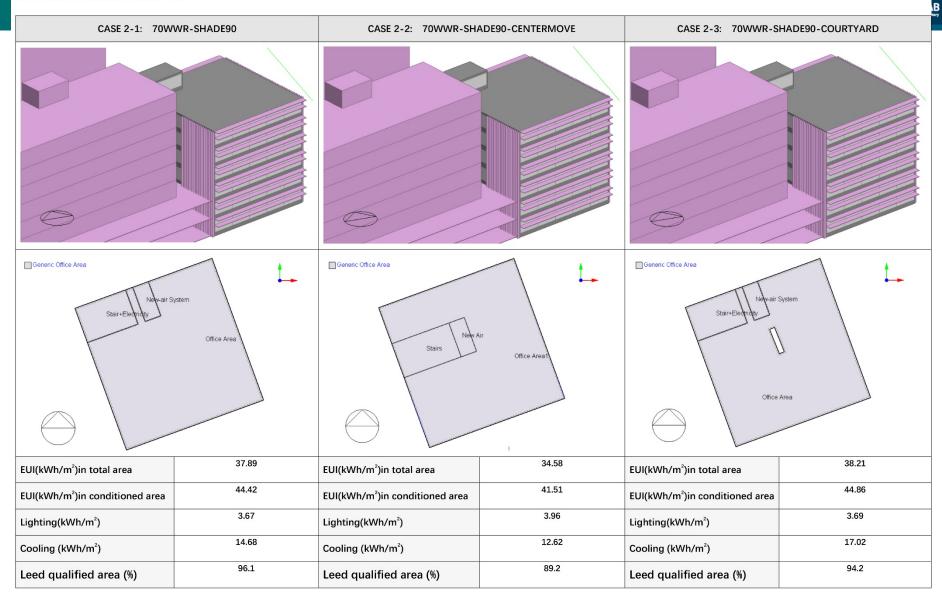


- 1. Shading design setting helps all models (40%WWR, 70%WWR and 100%WWR) has lower EUIs.
- 2. 40% and 70% WWR is the most suitable type for the Sino-US Low Carbon Building and Community Innovation Experimental Center as its low energy unit density and more LEED qualified area after the shading setting.
- 3. The difference between 40% and 70% is not significant on energy use. 100% is not recommended

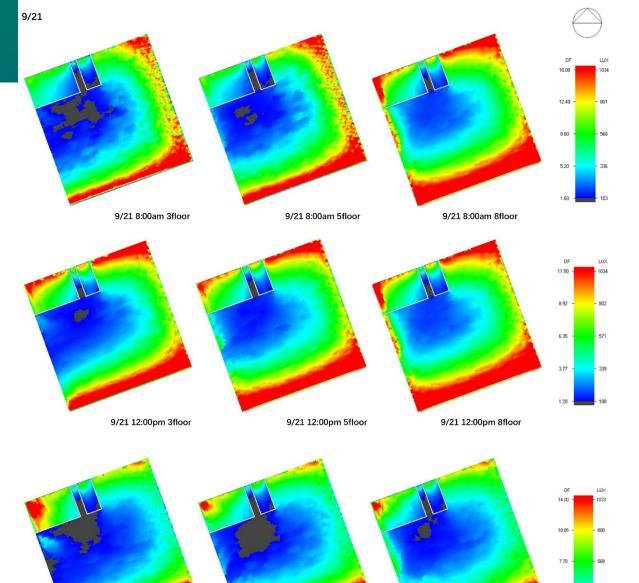


Part 2: Zoning

第二部分,建筑功能区域调整



Based on the former conclusion, models following are all with 70%WWR.



	Total Energy [kWh]	Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	167992.26	37.89	44.42
Net Site Energy	167992.26	37.89	44.42
Cooling	65806.62	14.68	17.57
Lighting	16451.66	3.67	4.39

4433.259
4260.881
96.1
PASS

Eligible zones for daylighting, worst case values for 9:00 and 15:00

4.55

9/21 16:00pm 8floor

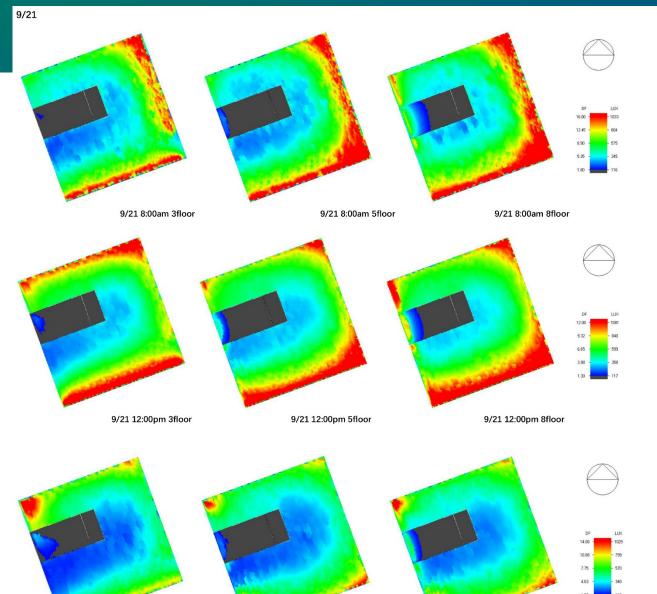
Zone	Floor area (m2)	Min Illumination (lux)	Working plane area within Limits (%)
Floor3:OfficeArea1	630.341	52.0	94. 3
Floor4:OfficeArea1	630.341	50.1	96. 9
Floor5:OfficeArea1	630.341	50.1	93. 8
Floor6:OfficeArea1	630.341	39.0	94. 6
Floor7:OfficeArea1	630.341	41.9	94. 7
Floor8:OfficeArea1	630.341	54.0	99. 3

Footer 19

9/21 16:00pm 5floor

9/21 16:00pm 3floor





	Total Energy [kWh]	Energy Per Total Building Area [kWh/m2]	Conditioned Building
Total Site Energy	155447.60	34.58	41.51
Net Site Energy	155447.60	34.58	41.51
Cooling	56555.87	12.62	15.10
Lighting	17764.15	3.96	4.74

Summary Results	
Total area (m2)	4495.720
Total area above threshold (m2)	4008.585
% Area within illuminance threshold limits	89.2
LEED v3 NC 2009 IEQ 8.1 Status	PASS

Eligible zones for daylighting, worst case values for 9:00 and 15:00

Zone	Floor area (m2)	Min Illumination (lux)	Working plane area within Limits (%)
Floor3:OfficeArea1	624.160	156.0	100.0
Floor4:OfficeArea1	624.160	154.4	100.0
Floor5:OfficeArea1	624.160	180.5	100.0
Floor6:OfficeArea1	624.160	165.2	100.0
Floor7:OfficeArea1	624.160	174.5	100.0
Floor8:OfficeArea1	624.160	187.3	100.0

Footer 20

9/21 16:00pm 3floor

9/21 16:00pm 5floor

9/21 16:00pm 8floor

9/21

2-3 70WWR-SHADE90-COURTYARD

	Total Energy [kWh]	Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	167860.33	38.21	44.86
Net Site Energy	167860.33	38.21	44.86
Cooling	63673.38	14.49	17.02
Lighting	16209.98	3.69	4.33

	Total Energy [kWh]	Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	167860.33	38.21	44.86
Net Site Energy	167860.33	38.21	44.86
Cooling	63673.38	14.49	17.02
Lighting	16209.98	3.69	4.33

Daylighting Credit - LEED v3 NC 2009 IEQ 8.1

Summary Results	
Total area (m2)	4392.996
Total area above threshold (m2)	4137.981
% Area within illuminance threshold limits	94.2
LEED v3 NC 2009 IEQ 8.1 Status	PASS

Eligible zones for daylighting, worst case values for 9:00 and 15:00

Zone	Floor area (m2)	Min Illumination (lux)	Working plane area within Limits (%)
Floor3:OfficeArea1	630.341	54.9	94.7
Floor4:OfficeArea1	622.289	45.6	93.0
Floor5:OfficeArea1	622.289	43.8	90.8
Floor6:OfficeArea1	622.289	39.0	91.0
Floor7:OfficeArea1	622.289	38.3	91.1
Floor8:OfficeArea1	622.289	52.2	99.4

9/21 8:00am 3floor	9/21 8:00am 5floor	9/21 8:00am 8floor
		DF UK 12:00 - 1094 9:30 - 640 6:60 - 556 3:90 - 392 1:20 - 108
9/21 12:00pm 3floor	9/21 12:00pm 5floor	9/21 12:00pm 8floor
		DF LUK 14.00 - 1029 10.86 - 789 7.72 - 559 4.59 - 337 1.45 - 197

21 Footer

9/21 16:00pm 5floor

9/21 16:00pm 8floor

9/21 16:00pm 3floor

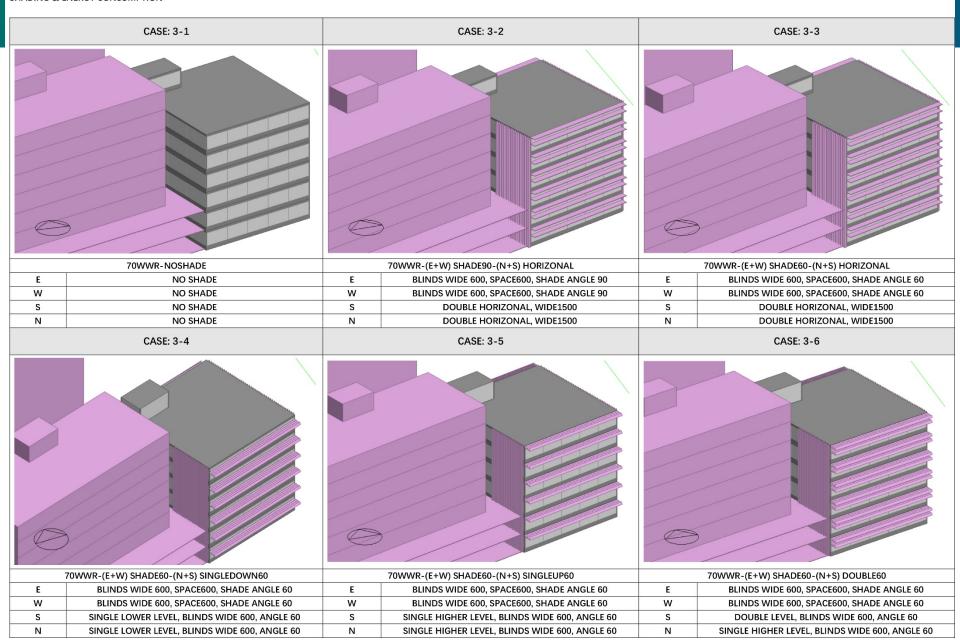
Conclusions on zoning



- 1. Space moving (case2-2) can help the building to decrease the EUI.
- 2. The courtyard (case3) can help the building to improve the daylighting, but the EUI will increase.



Part 3: Shading design 第三部分,遮阳设计



不同遮阳形式的能耗对比

Energy consumption in different shade

	CASE 3-1	CASE 3-2	CASE 3-3	CASE 3-4	CASE 3-5	CASE 3-6
	70WWR-NOSHADE	70WWR-SHADE90	70WWR-ESHADE60-	70WWR-ESHADE60-	70WWR-ESHADE60-	70WWR-ESHADE60-
	7000WR-NOSHADE	700000R-SHADE90	NHORIZONAL	NSINGLEDOWN60	NSINGLEUP60	NDOUBLE60
Total Site Energy [kWh]	177190.62	155447.60	149035.26	147472.41	149050.48	146248.42
Energy Per Total Building Area [kWh/m2]	39.53	34.58	33.25	32.90	33.25	32.62
Energy Per Conditioned Building Area [kWh/m2]	47.31	41.51	39.80	39.38	39.80	39.05
HVAC [kWh/m2]	25.82	19.47	17.45	17.88	18.30	17.51
Lighting [kWh/m2]	3.15	3.95	4.71	3.96	3.95	4.00
Heating [kWh]	0.67	0.99	1.06	1.03	1.00	1.08
Cooling [kWh]	76347.42	56555.87	51247.97	52281.85	53622.20	51001.54
Interior Lighting [kWh]	14122.71	17764.15	21104.98	17745.72	17704.33	17916.01
Exterior Lighting [kWh]	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment [kWh]	43251.48	44107.28	43251.48	43251.48	43251.48	43251.48
Exterior Equipment [kWh]	0.00	0.00	0.00	0.00	0.00	0.00
Fans [kWh]	12717.11	10892.84	9503.75	9698.84	9799.73	9716.38
Pumps [kWh]	2541.19	1872.17	1638.73	1697.49	1740.21	1654.91
Heat Rejection [kWh]	24116.16	18188.04	15845.97	16491.53	16856.17	16117.75

- CONCLUSION: 1) 南北向水平遮阳设计, 3-8 层应有所不同, 3 层出挑少, 8 层出挑多, 3-8 层越往上出挑越多;
 - 2) 东向适宜做垂直遮阳,单层,遮阳角度东偏北60度;
 - 3) 西向适宜做垂直遮阳,单层,遮阳角度西偏北60度;
 - 4) 北向应做单层水平遮阳,南向应做双层水平遮阳,水平遮阳出挑长度 2000 好于 1000;
 - 5) 水平遮阳百叶旋转60度后,南向宜做单层遮阳,下层遮阳对自然采光效果控制更优,但能耗值高于上层遮阳;

6) 双层水平遮阳百叶旋转 60 度后的总能耗值最低;



1-Energy Consumption

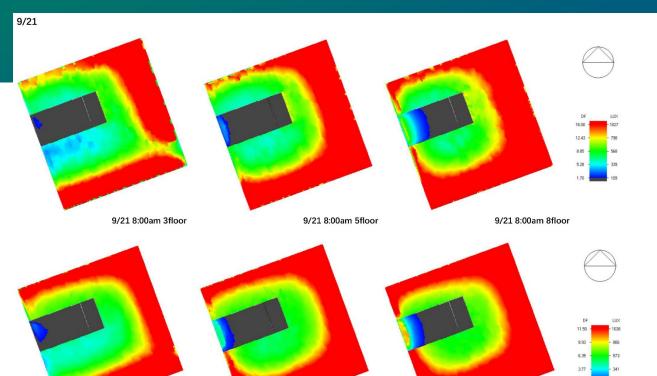
	Total Energy [kWh]	Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	177190.62	39.53	47.31
Net Site Energy	177190.62	39.53	47.31
Cooling	76347.42	17.03	20.39
Lighting	14122.71	3.15	3.77

2-Daylighting Credit - LEED v3 NC 2009 IEQ 8.1

4482.739
4001.452
89.3
PASS

Eligible zones for daylighting, worst case values for 9:00 and 15:00

Zone	Floor area (m2)	Min Illumination (lux)	Working plane area within Limits (%)
Floor3:OfficeArea1	624.160	215.5	100.0
Floor4:OfficeArea1	624.160	244.7	100.0
Floor5:OfficeArea1	624.160	386.7	100.0
Floor6:OfficeArea1	624.160	385.1	100.0
Floor7:OfficeArea1	624.160	368.9	100.0
Floor8:OfficeArea1	624.160	414.1	100.0



7.75 4.63 9/21 16:00pm 3floor 9/21 16:00pm 5floor 9/21 16:00pm 8floor

9/21 12:00pm 5floor

9/21 12:00pm 8floor

10.88

Footer 26

9/21 12:00pm 3floor

CASE3-2: 70WWR-(E+W)SHADE90-(N+S)HORIZONAL

1-Energy Consumption

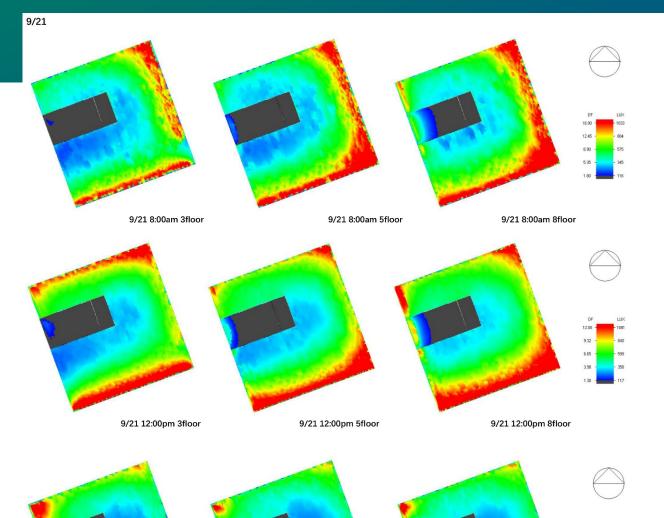
	Total Energy [kWh]	Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	155447.60	34.58	41.51
Net Site Energy	155447.60	34.58	41.51
Cooling	56555.87	12.62	15.10
Lighting	17764.15	3.96	4.74

2-Daylighting Credit - LEED v3 NC 2009 IEQ 8.1

Summary Results	
Total area (m2)	4495.720
Total area above threshold (m2)	4008.585
% Area within illuminance threshold limits	89.2
LEED v3 NC 2009 IEQ 8.1 Status	PASS

Eligible zones for daylighting, worst case values for 9:00 and 15:00

Zone	Floor area (m2)	Min Illumination (lux)	Working plane area within Limits (%)
Floor3:OfficeArea1	624.160	156.0	100.0
Floor4:OfficeArea1	624.160	154.4	100.0
Floor5:OfficeArea1	624.160	180.5	100.0
Floor6:OfficeArea1	624.160	165.2	100.0
Floor7:OfficeArea1	624.160	174.5	100.0
Floor8:OfficeArea1	624.160	187.3	100.0



Footer 27

9/21 16:00pm 5floor

9/21 16:00pm 8floor

9/21 16:00pm 3floor



1-Energy Consumption

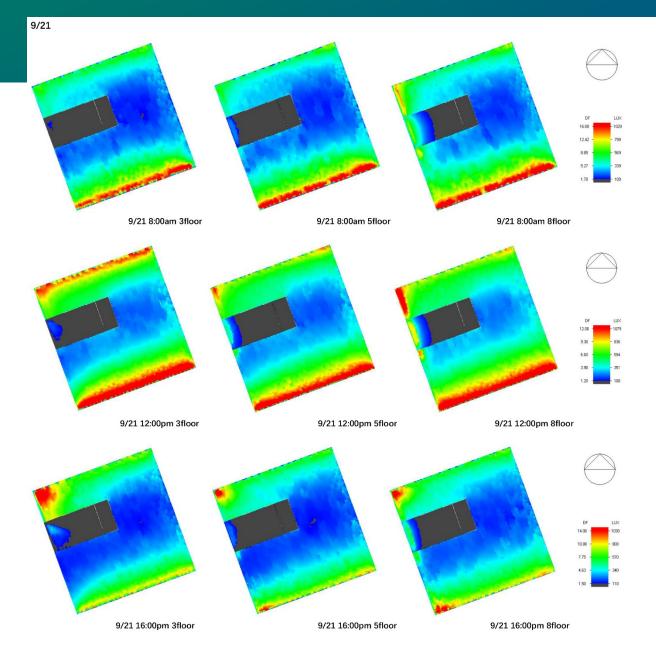
	Total Energy	Energy Per Total	Energy Per Conditioned Building
	[kWh]	[kWh/m2]	9
Total Site Energy	149035.26	33.25	39.80
Net Site Energy	149035.26	33.25	39.80
Cooling	51247.978	11.43	13.68
Lighting	21104.98	4.71	5.64

2-Daylighting Credit - LEED v3 NC 2009 IEQ 8.1

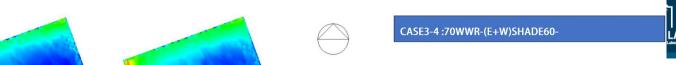
Eligible zones for daylighting, worst case values for 9:00 and 15:00

Summary Results	
Total area (m2)	4482.739
Total area above threshold (m2)	3995.744
% Area within illuminance threshold limits	89.1
LEED v3 NC 2009 IEQ 8.1 Status	PASS

Zone	Floor area (m2)	Min Illumination (lux)	Working plane area within Limits (%)
Floor3:OfficeArea1	624.160	131.6	100.0
Floor4:OfficeArea1	624.160	120.8	100.0
Floor5:OfficeArea1	624.160	125.9	100.0
Floor6:OfficeArea1	624.160	124.6	100.0
Floor7:OfficeArea1	624.160	115.0	100.0
Floor8:OfficeArea1	624.160	138.8	100.0







1-Energy Consumption

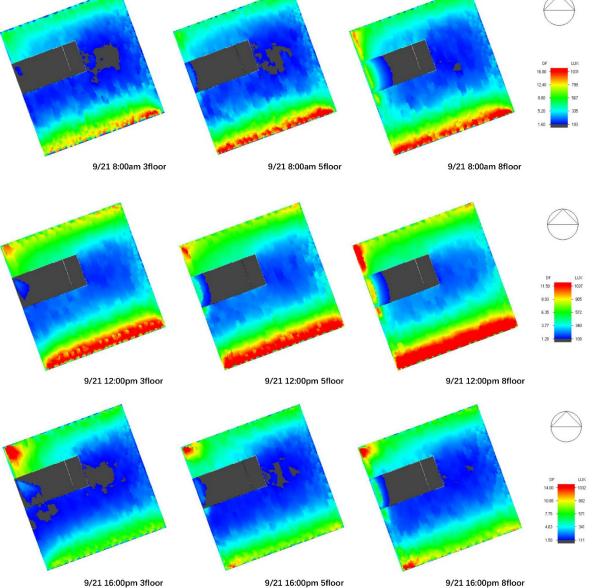
	Total Energy [kWh]	Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	147472.41	32.90	39.38
Net Site Energy	147472.41	32.90	39.38
Cooling	52281.85	11.66	13.96
Lighting	17745.72	3.96	4.74

2-Daylighting Credit - LEED v3 NC 2009 IEQ 8.1

Summary Results	
Total area (m2)	4482.739
Total area above threshold (m2)	3988.307
% Area within illuminance threshold limits	89.0
LEED v3 NC 2009 IEQ 8.1 Status	PASS

Eligible zones for daylighting, worst case values for 9:00 and 15:00

Zone	Floor area (m2)	Min Illumination (lux)	Working plane area within Limits (%)
Floor3:OfficeArea1	624.160	91.6	99.6
Floor4:OfficeArea1	624.160	90.4	99.7
Floor5:OfficeArea1	624.160	93.3	99.8
Floor6:OfficeArea1	624.160	98.4	99.8
Floor7:OfficeArea1	624.160	101.1	99.8
Floor8:OfficeArea1	624.160	114.5	100.0



9/21



9/21 8:00am 3floor

9/21 16:00pm 3floor

CASE3-5:70WWR-(E+W)SHADE60-

LAB Laboratory

1-Energy Consumption

	Total Energy [kWh]	Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	149050.48	33.25	39.80
Net Site Energy	149050.48	33.25	39.80
Cooling	53622.20	11.96	14.32
Lighting	17704.33	3.95	4.73

DF 1029 1029 11240 - 737 8890 - 556 529 - 334 1.50 - 103

9/21 8:00am 8floor

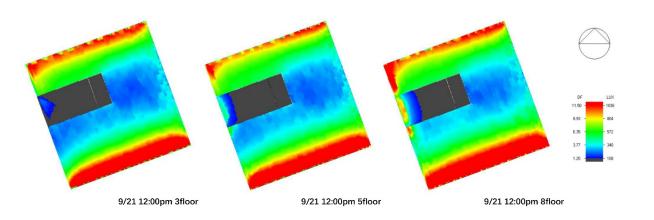
9/21 16:00pm 8floor

2-Daylighting Credit - LEED v3 NC 2009 IEQ 8.1

Summary Results	
Total area (m2)	4482.739
Total area above threshold (m2)	3996.144
% Area within illuminance threshold limits	89.1
LEED v3 NC 2009 IEQ 8.1 Status	PASS

Eligible zones for daylighting, worst case values for 9:00 and 15:00

Zone	Floor area (m2)	Min Illumination (lux)	Working plane area within Limits (%)
Floor3:OfficeArea1	624.160	108.7	100.0
Floor4:OfficeArea1	624.160	128.6	100.0
Floor5:OfficeArea1	624.160	136.2	100.0
Floor6:OfficeArea1	624.160	127.9	100.0
Floor7:OfficeArea1	624.160	123.0	100.0
Floor8:OfficeArea1	624.160	131.8	100.0



9/21 8:00am 5floor

Footer 30

9/21 16:00pm 5floor

CASE3-6:70WWR-(E+W)SHADE60-(N+S)DOUBLE60

1-Energy Consumption

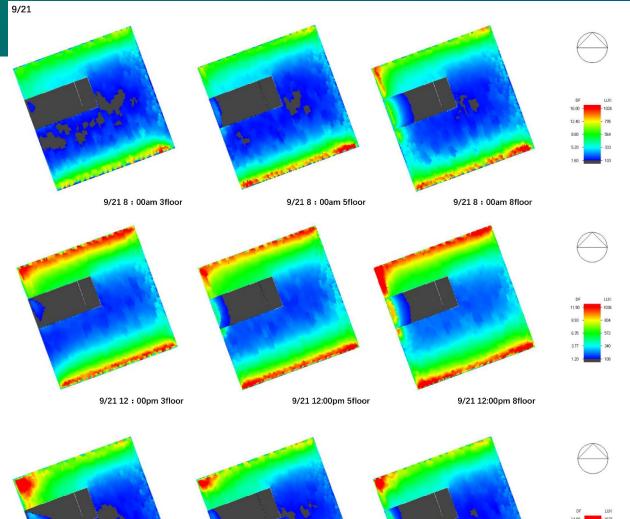
	T-1-1 F	Energy Per Total	Energy Per
	Total Energy	Building Area	Conditioned Building
	[kWh]	[kWh/m2]	Area [kWh/m2]
Total Site Energy	146248.42	32.62	39.05
Net Site Energy	146248.42	32.62	39.05
Cooling	53622.20	11.96	14.32
Lighting	17704.33	3.95	4.73

2-Daylighting Credit - LEED v3 NC 2009 IEQ 8.1

Summary Results	
Total area (m2)	4482.739
Total area above threshold (m2)	3986.987
% Area within illuminance threshold limits	88.9
LEED v3 NC 2009 IEQ 8.1 Status	PASS

Eligible zones for daylighting, worst case values for 9:00 and 15:00

Zone	Floor area (m2)	Min Illumination (lux)	Working plane area within Limits (%)
Floor3:OfficeArea1	624.160	87.8	99.6
Floor4:OfficeArea1	624.160	82.6	99.5
Floor5:OfficeArea1	624.160	98.5	100.0
Floor6:OfficeArea1	624.160	99.9	99.8
Floor7:OfficeArea1	624.160	99.5	99.7
Floor8:OfficeArea1	624.160	113.4	100.0



31 Footer

9/21 16:00pm 5floor

9/21 16:00pm 8floor

9/21 16:00pm 3floor

Conclusions on shading design:



- 1. Vertical shading on east and west facade can improve the daylighting and decrease the EUI.
- 2. Double horizontal shading (70% WWR) in south and north can improve the daylighting and decrease the EUI.
- 3. Interior shading will be researched in the next round.



Part 4: Natural Ventilation Design 第四部分,自然通风设计

Model Settings



Test Cases	Descriptions	Schedule	System Setting	Window Opening
Baseline	Mechanical Cooling and Ventilation for the office spaces	Whole year	 4-pipe FCU with OA & 	0%
Case 1	1	Mechanical Cooling+Vent: May to Oct;	No Heating Cooling Setpoing: 26 °C Occupied Schedules: 7am to 20pm Mon to Fri Summer Clo=0.5	5%
Case 2				15%
Case 3				25%
Case 4		Natural Ventilation: Jan to Apr & Nov to Dec.	• Winter Clo=1.0	35%
Case 5		т		45%
Case 6				50%

Notes: 1) Windows are set to open on top.

- 2) Modeled building total area is 4451.36 m².
- 3) Modeled net conditioned area is 3794.97 m².
- 3) Cases are modeled in DesignBuilder v5 with Energy+ v8.

Preliminary Results: Energy Consumptions Comparison



Test Cases	Description	Building Total Energy (KWh)	Energy Per Net Conditioned Building Area (kWh/m2)	Total Energy Difference (%)	Cooling Energy Per Net Conditioned Building Area (KWh/ m2)	Cooling Energy Reduction (%)
Baseline	MC+MV	195577.96	51.54	-	23.26	-
Case 1	NV 5%Open	167458.37	44.13	-14.4%	17.89	-23.1%
Case 2	NV 15%Open	166954.61	43.99	-14.6%	15.29	-34.3%
Case 3	NV 25%Open	175113.99	46.14	-10.5%	14.92	-35.9%
Case 4	NV 35%Open	184837.28	48.71	-5.5%	14.96	-35.7%
Case 5	NV 45%Open	195233.69	51.45	-0.2%	15.18	-34.7%
Case 6	NV 50%Open	200549.3	52.85	2.5%	15.32	-34.1%

Preliminary Results: Thermal Comfort Comparison



Thermal Comfort PMV Values in Offices During Occupied Hours				
Test Cases	Description	Average	Max	Min
Baseline	MC+MV	0.42	1.24	0.07
Case 1	NV 5%Open	0.36	1.26	-0.07
Case 2	NV 15%Open	0.16	1.23	-0.24
Case 3	NV 25%Open	0.12	1.22	-0.27
Case 4	NV 35%Open	0.10	1.21	-0.29
Case 5	NV 45%Open	0.09	1.21	-0.29
Case 6	NV 50%Open	0.09	1.21	-0.30

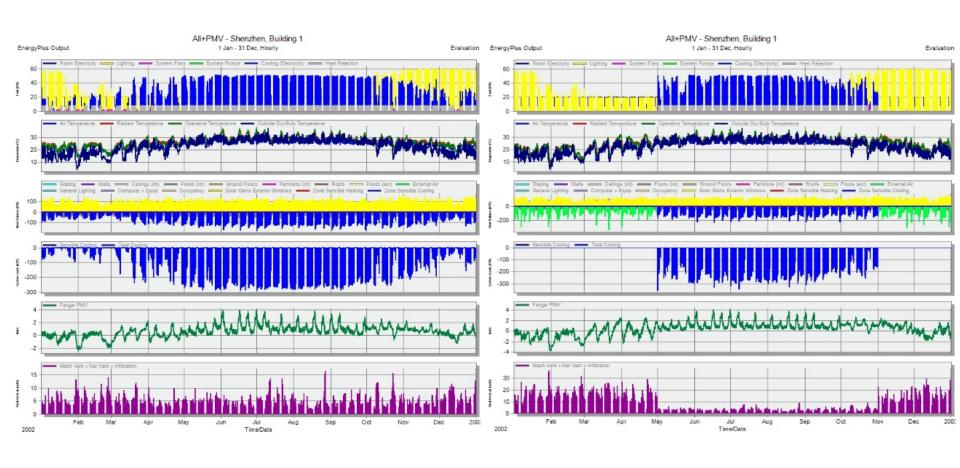
The results indicate that the PMV value decreases with larger window opening area.

Whole Building Annual Performance Comparison



Mechanical Cooling+Ventilation

Natural Ventilation with 15% window opening

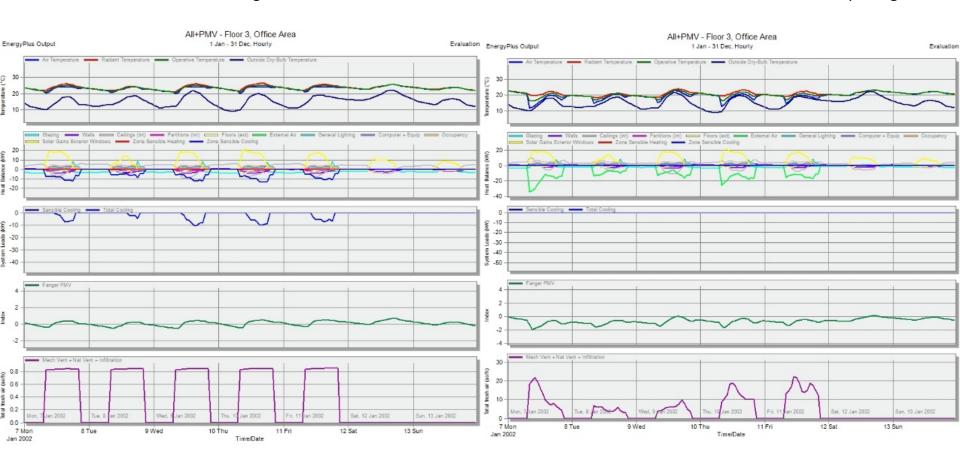


Office Space on Floor 3 Performance Comparison in a Typical Week in January



Mechanical Cooling+Ventilation

Natural Ventilation with 15% window opening

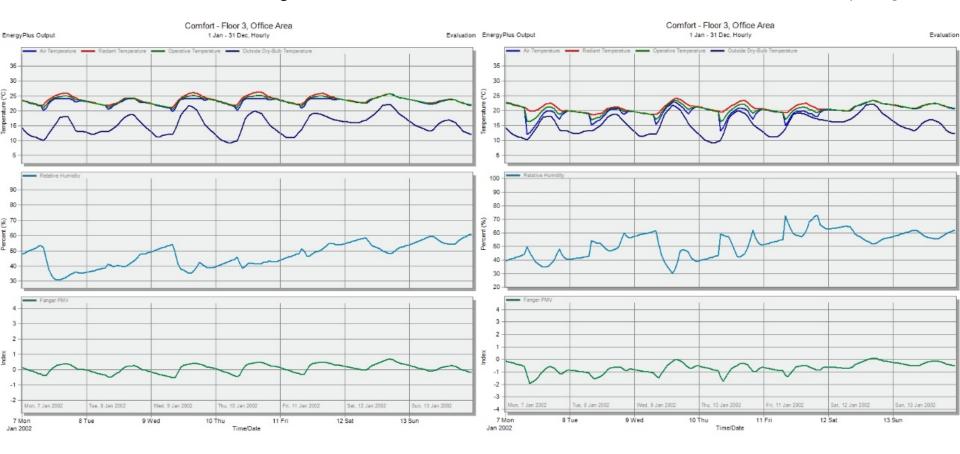


Office Space on Floor 3 Temperatures and PMV Comparison in a Typical week in January



Mechanical Cooling+Ventilation

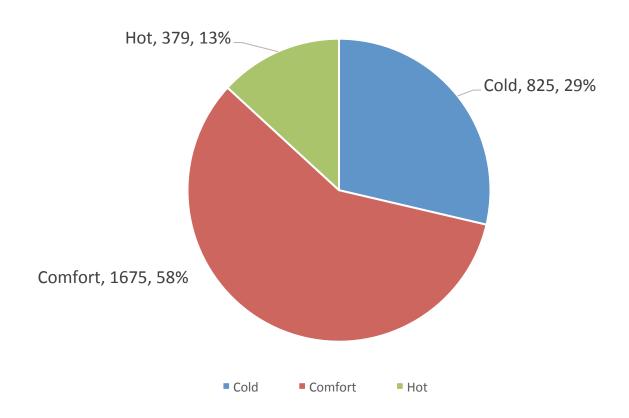
Natural Ventilation with 15% window opening



Natural Ventilation Thermal Comfort Distribution



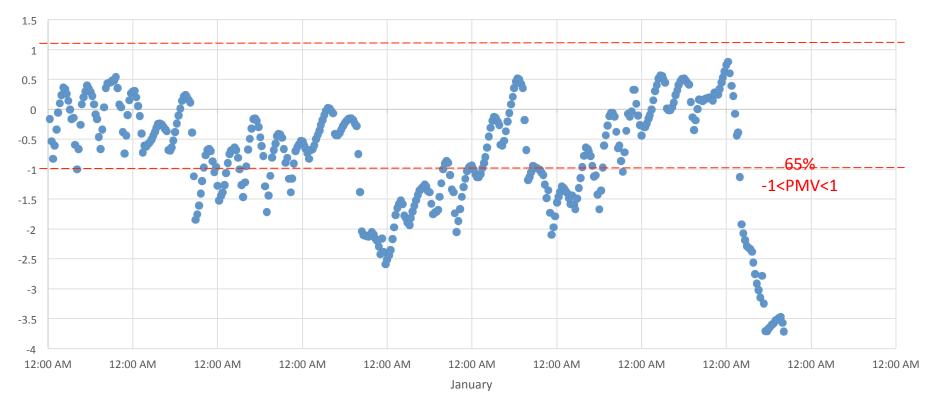
PMV Values for Office on Floor 3 with NV 15% window opening in January to April



Natural Ventilation PMV Distribution During Occupied Hours in January



PMV for Offices during occupied hours - NV with 15% window opening

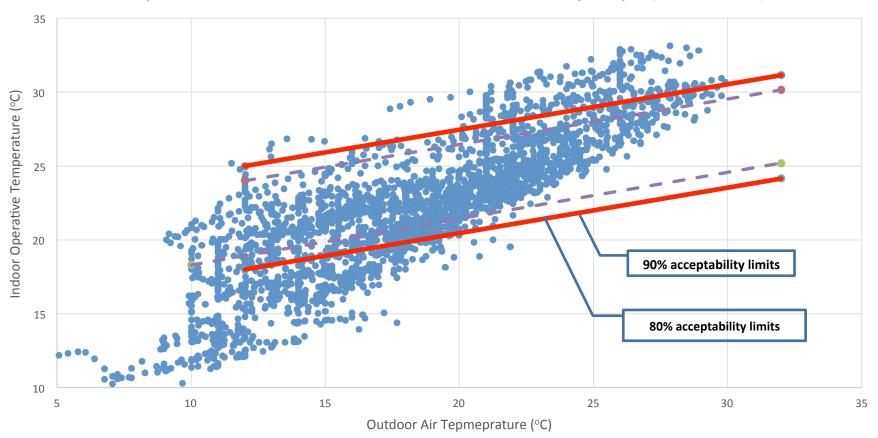


ASHRAE Std 55 Adaptive Method for Natural Ventilation """



January to April

Adaptive Thermal Comfort for Natural Ventilation in January to April (Floor 3 Office)

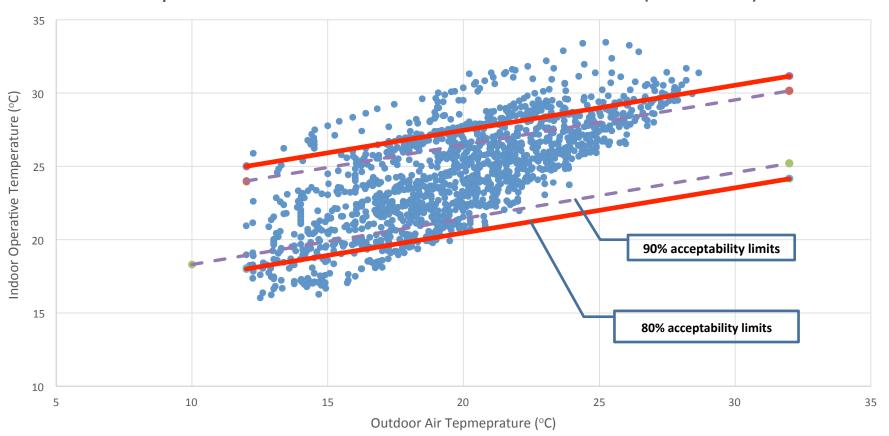


ASHRAE Std 55 Adaptive Method for Natural Ventilation



November to December

Adaptive Thermal Comfort for Natural Ventilation in Nov and Dec (Floor 3 Office)



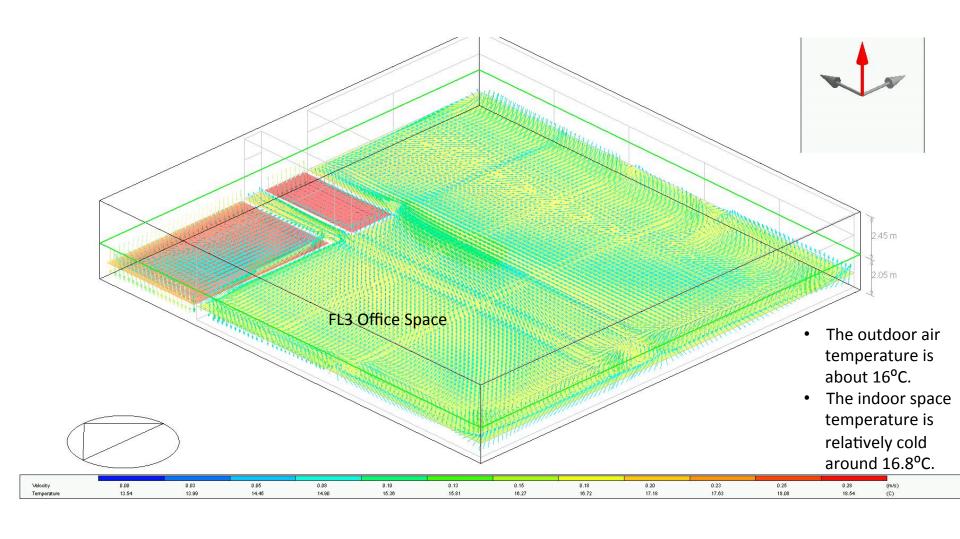
Natural Ventilation CFD Analysis



- Case Study: a winter typical weekday in January
- Floor 3 Office Space: natural ventilation with window 15% open on top
- Clothes value: winter CLO = 1.0
- CFD model: K-E model
- Boundary conditions are calculated with the typical winter week conditions.

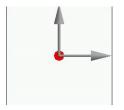
Natural Ventilation CFD – Temperature and Velocity Contour at the Seat Level



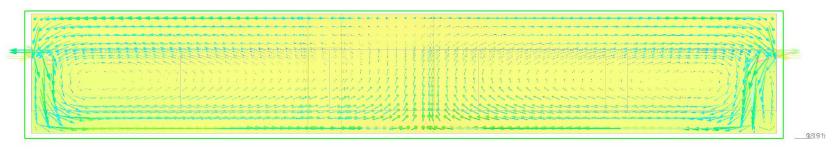


Natural Ventilation CFD – Temperature and Velocity Contour at the room center





FL3 Office Space (Face to North)

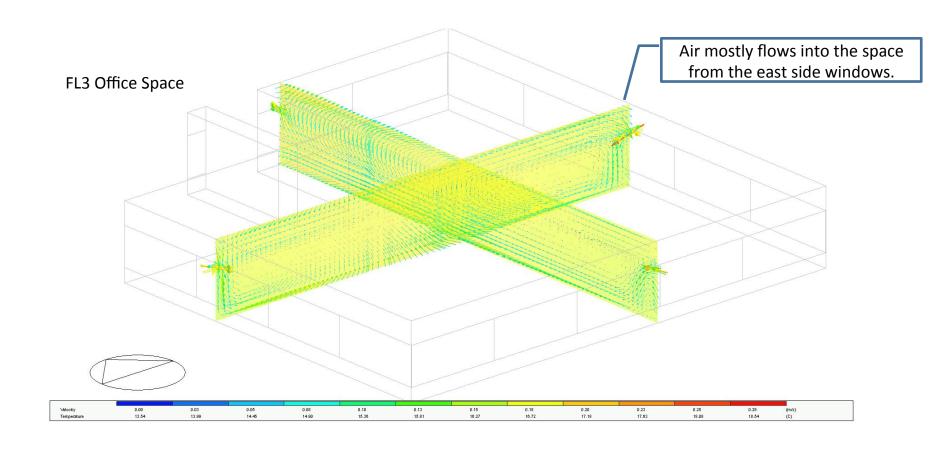


• It clearly shows the cold air flows downwards from the top of the window to the floor.



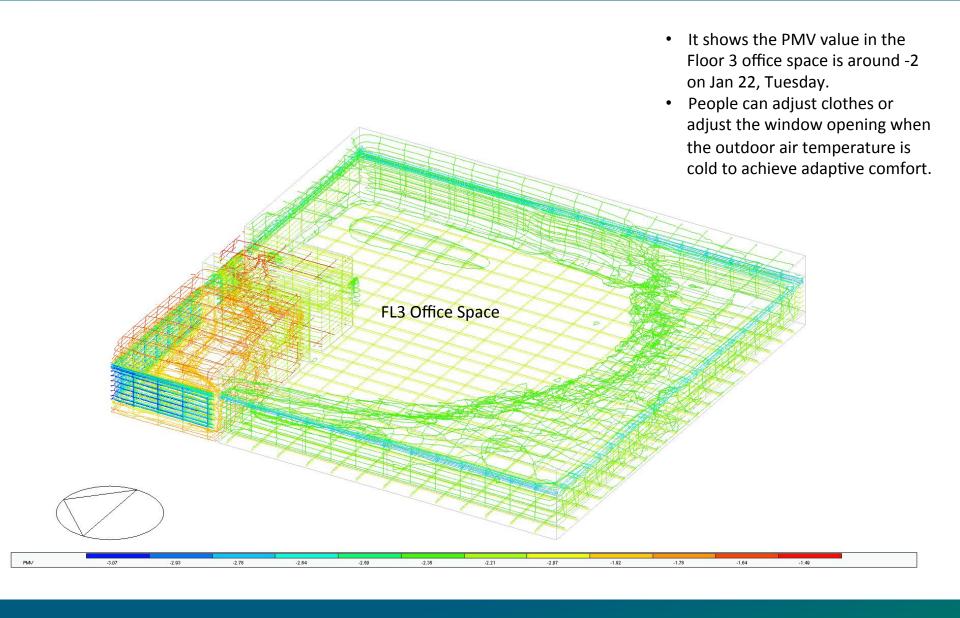
Natural Ventilation CFD – Temperature and Velocity Contour at the room center





Natural Ventilation CFD – Thermal Comfort PMV





Future Studies



- CFD analysis with different wind directions
- CFD analysis with different window open direction
- Find the appropriate operation schedule for natural ventilation
- Mixed mode operation with natural ventilation and mechanical cooling



Thank you Questions?